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The Effect of Meltwater, Refreezing and Modelled Grain Size on Snow Albedo: Gaining Knowledge from Observations at Weather Stations and Numerical Modelling

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Motivation

The extent to which snow and ice surfaces undergo melt is mainly dictated by their absorption of shortwave radiation, and thus the surface albedo is a critical parameter for accurately modelling the surface energy balance and mass balance of the Greenland Ice Sheet (GrIS). Multiple variables affect the surface albedo, including the atmospheric conditions, solar zenith angle (SZA), and characteristics of the snowpack, such as grain size, shape and orientation; snow depth; and liquid water content.

Whilst accurate models of snow albedo exist at the scale of individual crystals, these cannot be scaled for larger areas, and thus a simplified parameterisation is desired. Many parameterisations employ either Temperature-Dependent or Prognostic schemes, respectively using surface temperatures or albedo decay rates to simulate changes in the snowpack. However, these schemes are not physically-meaningful and subsequently may be specific to certain locations or conditions. This thesis therefore aims to formulate a novel parameterisation for surface albedo that is physically-meaningful and applicable to any time or location by employing a Detailed albedo scheme, which exploits the snowpack's characteristics but remains computationally-feasible enough for inclusion in Regional Climate Models (RCM).

Approach

Shortwave albedo measurements are taken from the Programme for Monitoring the Greenland Ice Sheet (PROMICE; Ahlstrøm et al., 2008), which maintains a network of automatic weather stations (AWS) across the GrIS. These stations provide continuous updates of weather conditions, used here to force a firn evolution model originally developed as a subsurface scheme for the HIRHAM5 RCM by Langen et al. (2015), and subsequently updated by Langen et al. (2017) and Vandecrux et al. (submitted).

The firn model provides an hourly time series of key snowpack variables (e.g. grain size, density, liquid water content), and these variables will be correlated with the AWS-measured albedo to uncover the extent and nature of their contribution. These variables are viewed as either *predictive* variables that will drive albedo variation, or as *segregative* variables that differentiate between separate parameterisation regimes. Additionally, the potential impact of refreezing will be assessed, with meltwater retention, percolation and drainage understood to be an important factor in correctly simulating snow albedo.

Initially, focus will be on the Kangerlussuaq Upper (KAN_U) station in western Greenland (67.0003°N, 47.0253°W). Once a scheme has been developed at KAN_U, it will be tested at other PROMICE sites, and, if time permits, any necessary adaptions these tests reveal will be integrated to the scheme. Finally, the performance of the developed scheme will be compared to existing schemes, such as HIRHAM5's original Temperature-Dependent scheme and an updated Prognostic approach (Nielsen-Englyst, 2015).

Conclusions

Early investigations at the KAN_U station confirm the dominant role of the SZA on diurnal albedo fluctuations. Large inter- and intra-annual variability is apparent in correlations between AWS-measured albedo and snowpack variables from the firn model; work is currently focused on determining whether specific conditions (e.g. extended melt periods, frequent snowfall events) and the SZA can explain this variation. Work to incorporate the effects of cloud cover is also ongoing. It is expected that the developed scheme will be largely driven by grain size and the SZA, modified to account for cloud cover. Contributions from precipitation and melt events are expected to explain more extreme values.

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